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Design of an on-line rapid detection system of the density for emulsion explosives

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Abstract

Although the automatic production of emulsion explosives has been realized, the density of emulsion explosives is still detected by the off-line method. This paper presents a new on-line rapid detection method for the emulsion explosives, an on-line detection system for the density with the function of alarm, feedback and adjustment. Moreover, the calibration and verification of the system have been conducted. The research result shows that the rapid detection and adjustment for the density of emulsion explosives with arbitrary shape and unfixed volume can be realized by the system, and the density measured accorded with the requirements for detection accuracy.

Keywords: emulsion explosives; density; automatic sampling; on-line; rapid measurement

Nomenclature

m_1	the mass of 1#weighing system(g)
m_2	the mass of 2#weighing system(g)
ρ	the density of the sample(g/cm^3)
L	digital quantity of the frequency converter
F	frequency of the frequency converter(Hz)
I_1	the current of 1#weighing system(mA)
I_2	the current of 2#weighing system(mA)
Error	the error of the density of emulsion explosives(%)
ρ_s	the density standard value(g/cm^3)

1. Introduction

With the wide application of emulsion explosives, its quality is paid more and more attention. Density is one of the important performance parameters of emulsion explosives, and it would affect detonation sensitivity, detonation velocity, performance, and even the production quality[1]. Emulsion explosives have become the leading products of industrial explosives in China. The production technique of emulsion explosives experienced 3 stages, that is from intermittent, semi-continuous to continuous. However, the off-line method still is used to detect the density of emulsion explosives. It can't meet the demand of the continuous production of emulsion explosives.

There are many detection methods, such as hydrostatic weighing method, float meter method, density cup method, cylinder method, weighing method and drainage method. However, these methods belong to off-line detection methods.

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There are many on-line detection methods, such as ultrasonic method, vibration method, γ-ray method and photoelectric detection method[2]. The ultrasonic method is a method utilizing the reflection and refraction principle of the wave[3]. The vibration method mainly considers the characteristics of the different resonance frequencies of liquid[4]. Photoelectric method is a method detecting by absorption luminous flux[5]. γ-ray method generally is used to detect the relative variation of the density compared with standard density[6]. However, emulsion explosives are very sensitive to external energy. So these methods could initiate explosion of emulsion explosives. Thus, it is necessary to design a safety on-line detection method for the density of emulsion explosives.

2. Design of an on-line rapid detection system of the density

2.1. Design idea of the detection system

The single weighing system for the detection of semi-finished product of emulsion explosives has been designed by our research group[7]. Only if the volume of the sample is known, its density could be detected by this system. However, this system can't realize on-line sampling. Therefore, a new on-line detection system of the density for emulsion explosives should be designed on the basis of previous work.

A new parallel weighing system would be designed in this paper. And it could weigh the mass of emulsion explosives and drainage. Then the density could be obtained by the density calculation program. If the density value is larger or smaller than preset value, the system will alarm or stop. At the same time，this signal will be fed back to the control system to adjust the frequency of converter and the speed of motor, and further to adjust the density. The system closed-loop control chart is shown in Fig 1.

2.2. Establishment of the detection system

2.2.1. Function module of the detection system

The detection system includes parallel weighing module, control module, speed regulating module, alarm and feedback module, and touch screen module. The parallel weighing module could weigh the mass of emulsion explosives and drainage, and convert the physical quantity to the analog signal. The control module is used to acquire the signal from the parallel weighing module, to control the signal of alarm, to feed back and to display. The speed of feeding motor can be adjusted by the speed regulating module. The alarm and feedback module could alarm and stop the system when a unqualified signal was fed back. The touch screen module is convenient for man-machine interactive control. Composition and circuit principle of the system was shown in Fig.2.

2.2.2. Working principle of the detection system

Firstly, the mass was detected as a physical quantity，then converted to an analog signal by the parallel weighing system. The control system converted the analog signal to the digital signal which could be used to calculate and control. In order to display parameters, to alarm and to control frequency converter, the analog signals were converted to the digital signals. If the density was in the preset scope, the converter will keep the original frequency. If the density was out of the preset scope, the system will alarm, stop or change the speed of motor. Then, the system will start next detection of the density. The work flow chart of the system was shown in Fig.3.

2.2.3. Hardware choice and software design of the detection system

⑴ Design and selection of hardware.

① Parallel weighing system.

The parallel weighing system was designed to realize on-line sampling of emulsion explosives. Because of high precision, good frequency response and stable performance, digital resistance strain type weighing sensor was selected in the parallel weighing system to acquire the mass of emulsion explosives and drainage.

② Control system.

Because the detection system was a single control system, Siemens S7-200 PLC(CPU 224XP) was used. It provided communication ports to connect PC and to touch screen. EM231 analog input module was selected to input the analog signal and to transmit this signal to control system.

③ Frequency speed regulating system.

Siemens MicroMaster440 frequency converter was applied. It was used to control the frequency and to adjust the density of emulsion explosives automatically. Considering the safety of the production line of emulsion explosives, YB series of explosion-proof motors was chosen.

④ Touch screen system.

Siemens TP170 touch screen was used in order to interact conveniently. It could acquire the parameters signal transmitted from control system and display them.

(2) Software design.

For the control system， ladder diagram language was utilized to design program of the system. After an improvement，the sample density with arbitrary shape and unfixed volume could be obtained.

The touch screen system was based on WinCC flexible 2005 configuration software. The main interfaces of the system include a friendly interface, a parameter detection interface and a button control interface. It could offset the defects of original interfaces. These interfaces were shown in Fig 4.

Based on the above design, selection of hardware and improvement of software, a new online detecting system of the density was established.

2.2.4. Calibration of the detection system

The relation between the mass and the current was calibrated (shown in Fig.5). The mass scope is 0-1000g.

From Fig.5, there was a good linear relation between the weight mass and the current for the weighting system.

$$I = 0.0160m + 3.9892 \tag{1}$$

Therefore, it is easy to calculate the current by equation (1) after measuring the mass of emulsion explosives and drainage. Then, the density of sample can be calculated by the density calculation program.

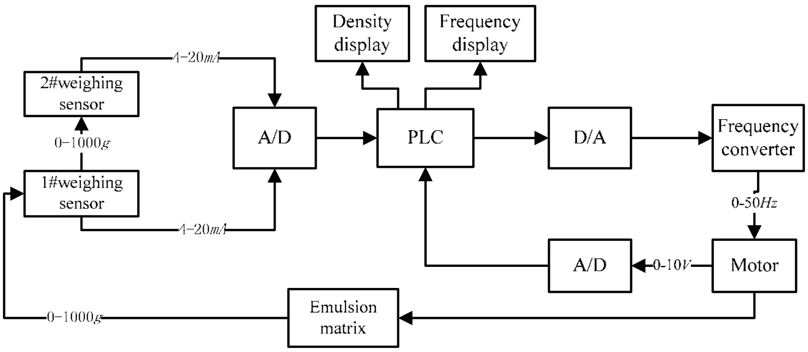

Fig. 1. System closed-loop control.

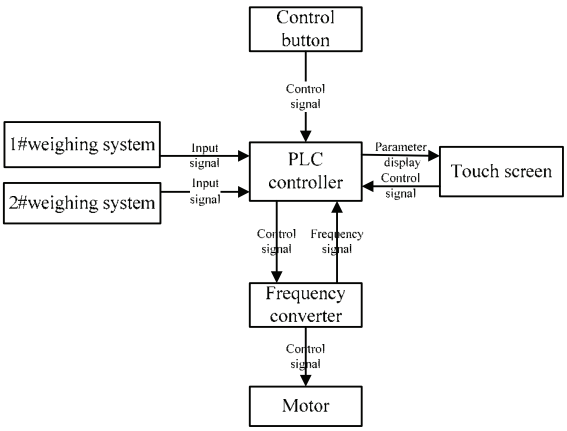

Fig. 2. Composition and circuit principle of the system.

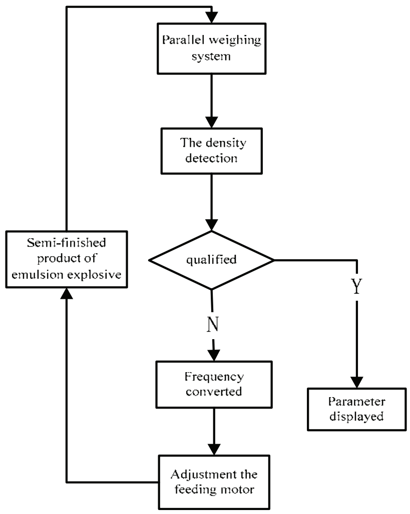

Fig. 3. Working principle diagram of the system.

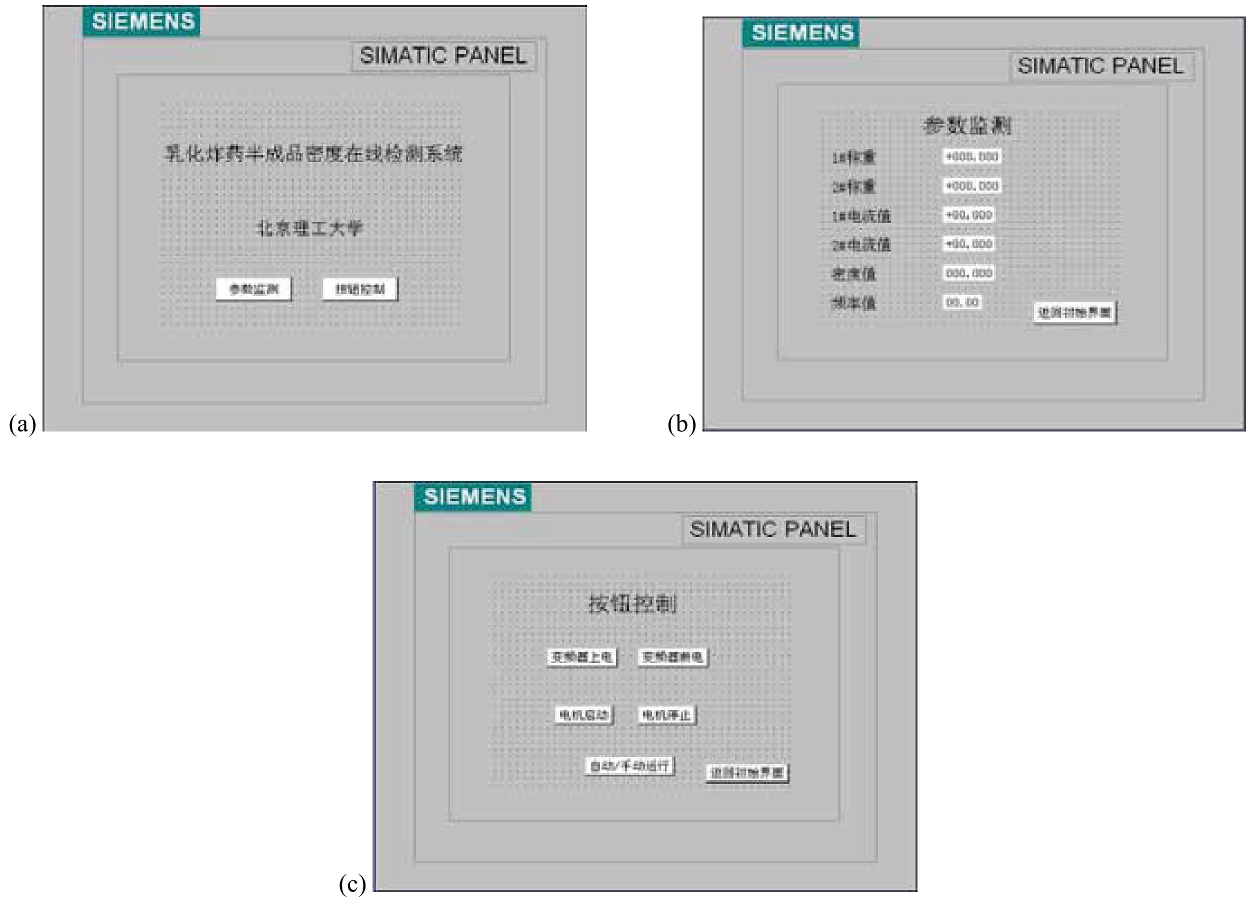

Fig. 4. Main function interfaces of (a) Friendly interface of online detection system, (b) parameter monitor interface of online detection system and (c) press-button control interface of online detection system.

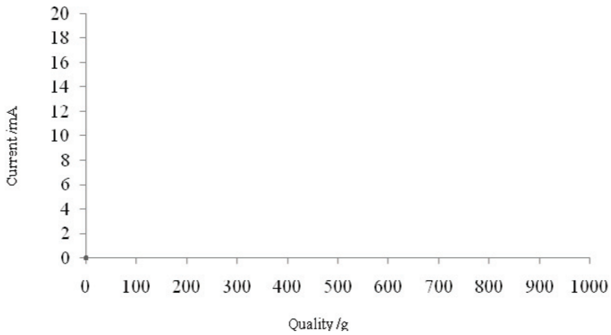

Fig. 5. Change of the current with the mass.

3. Verification of the detection system

3.1. Measurement of the density of steel

The steel with arbitrary shape and unfixed volume was used to verify the system. Its standard density value is 7.93g/cm^3. The result of the experiment was listed in Table 1.

Table 1. Experimental data of steels density measurement

No.	m_1/g	m_2/g	ρ/(g/cm3)	L	F/Hz
1	174.296	766.227	8.334	19200	30.00
2	182.152	812.664	7.205	12800	20.00
3	187.902	859.002	7.886	14400	22.50
4	193.742	899.719	7.909	16000	25.00
5	201.007	946.352	7.785	14400	22.50

It was shown that the new detection system could detect the density of the steel with arbitrary shape and unfixed volume.

3.2. Measurement of the density of emulsion explosives

The density of emulsion explosives with arbitrary shape and unfixed volume was detected by the system. The density standard value of the sample was 1.41g/cm^3. The detection results were listed in Table 2.

Table 2. Measuring data of the density of emulsion explosives measurement

No.	m_1/g	I_1/mA	m_2/g	I_2/mA	ρ/(g/cm^3)	Error/%	ρ_s/(g/cm^3)
1	187.124	6.995	188.293	7.012	0.91	76.4	
2	206.777	7.294	202.445	7.239	1.16	58.7	
3	228.601	7.643	217.184	7.475	1.273	9.7	1.41
4	248.617	7.963	231.461	7.704	1.306	6.7	
5	282.340	8.518	853.570	17.656	1.472	4.39	
6	325.336	9.206	874.176	17.986	1.474	4.54	

As shown in Table 2, the accuracy of measurement which resulted from the surface tension of water increases with the increase of emulsion explosives mass. The smaller the sample mass is, the more relative surface tension to overcome is. However, the surface tension decreased with the increasing of the quantity of sample, and even it can be ignored.

4. Conclusions

It has been shown that there is a good linear relation between the mass and the current for the new weighing system. On-line sampling weighing and rapid detecting for the emulsion explosives with arbitrary shape and unfixed volume can be realized by this system. When the mass of the sample is more than 75g, the density detection accuracy can meet the requirements.

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